Do central country authors of international co-authored publication networks obtain a high research impact?

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ABSTRACT

Do central country authors of an international co-authored publication network obtain a high research impact from their international co-authored publications? This study addressed the issue by examining countries' quantity of scientific publications. We proposed that countries with fewer scientific publications would gain more benefits from their central positions (both degree centrality and betweenness centrality) because their authors' limited domestic scientific knowledge motivated them to share and access more knowledge during the collaborations. Data from international co-authored publications in the creativity field from 29 countries during 2000-2014 provided support for the hypotheses. Suggestions for international research collaboration policy making are discussed.

Keywords: International co-authored publication network; Country citation counts; Degree centrality; Betweenness centrality; Countries' amount of scientific publications

INTRODUCTION

The percentage of all scientific articles that are internationally co-authored has more than doubled in twenty years (Wagner, Park and Leydesdorff 2015; Nguyen, Ho-Le and Le 2017). The number of a country's international co-authored publications is related to its scientific capacity, such as the number of trained science, technology, engineering, and mathematics workers (Ynalvez and Shrum 2011; Mêgnigbêto 2013). However, an interesting phenomenon is that some small countries have a higher level of international research collaborations than some big countries (Glänzel 2001; van Raan 1997).

One explanation may be that there are fewer opportunities to find collaborators and resources inside their own country compared with those available in larger countries (Narin, Stevens, and Whitlow 1991). Also, some governments of smaller countries (e.g. South Korea; cf. Kwon et al. 2012) deliberately invest in 'internationalization.' Thus, small countries' international co-authored publications increasingly account for a large percentage of their total publications (Luukkonen, Persson, and Sivertsen 1992; Muhonen, Puuska, and Leino 2012). Scholars have long observed that smaller countries seek to increase their research connections with larger, more developed countries such as the US and UK (Allen, Piepmeier, and Cooney 1971; Safahieh, Sanni, and Zainab 2012).

https://dx.doi.org/10.22452/mjlis.vol22no3.1

Although different countries may have different reasons for international collaborations, the consistent goal is to obtain a greater research impact from international co-authorships (Aman 2016). A widely-used index of scientific research impact is the citation count (Garfield 1962; Zainal and Zainab 2011). Scholars have noticed that international co-authored publications are cited more frequently than inter-organizational co-authored publications (van Raan 1998; Sooryamoorthy 2009), and domestic cross-institutional co-authored publications (Narin, Stevens, and Whitlow 1991; van Raan 1998; Glänzel 2001; Sooryamoorthy 2009; NordForsk 2010; Muhonen, Puuska, and Leino 2012). However, not all countries benefit from their citation count in the same way. For example, US ecologists received more citation counts than their European partners in the ecology field (Leimu and Koricheva 2005). It has been suggested that the citation count of international co-authored publications might depend on the characteristics of the country and the research field (Glänzel 2001).

The purpose of the present study is to identify factors that lead countries to receive a higher level of citation counts from their international co-authored publications. Given the growth of connections at the international level, it is helpful to examine the phenomenon as a communications network and to consider the network as a new organization on the world stage that adds to and complements national systems (Wagner, Park, and Leydesdorff 2015).

LITERATURE REVIEW

Centrality of International Collaborative Networks and Country Citation Counts

Centrality is an important structural attribute of social networks that precedes power or prominent status of an actor (Burkhardt and Brass 1990). An actor with high centrality can reach more actors through fewer intermediaries and occupies a strategically significant position in the overall structure of the network (Li, Liao, and Yen 2013). Centrality is a structural characteristic which can capture the patterns of knowledge transfer in research networks (Breschi and Catalini 2010). It can also reflect a country's organizational influence in terms of the extent to which it acts as an intermediary, and the degree of its access to or control over resources (Brass 1984). Central structural positions provide favorable conditions for collaborators to share, integrate, learn and utilize complementary or heterogeneous resources, such as information, science, technology, and knowledge (Borgatti 2005). Moreover, central actors often occupy critical gate-keeping positions (Valente 2012). Previous research has found that countries with high centrality enjoy more advantages related to research performance (Chen and Guan 2015). First, existing evidence supports the idea that a country with high centrality has an information advantage, which allows it to easily bridge the information gap between tripartite relationships (Gilsing et al. 2008; Anderson 2008). Second, previous studies found that actors with high centrality exercise more control in their network (Rowley 1997; Yan and Ding 2009; Eldon, Chien, and Hsiuju 2013; Wang et al. 2014). Finally, countries with high centrality have a considerable capacity to bear risk, adapt to structural changes, and reach a position of high status and high prestige (Ahuja, Soda and Zaheer 2012).

Freeman (1979) conceptually clarified the most commonly used measurements of centrality: degree centrality (DC) (e.g. Wang et al. 2014) and betweenness centrality (BC) (e.g. Li, Liao, and Yen 2013). DC is the number of a specific node's edges, without accounting for the strength (Freeman 1979). In the context of our weighted networks, each edge means collaboration frequency between two countries. As a central node with high DC, a country has scientific publications co-authored with people from many other countries. Research has found that researchers and organizations with a high level of DC had more citation counts (Yan and Ding 2009; Wang et al. 2014; Oguz, Kinglsey, and John 2014), and a higher g-index (Abbasi, Altmann, and Hossain 2011). A recent study found that, even after taking the journal impact factor, citation count, and research awards into consideration, DC positively influenced scientists' research performance (Liao 2011). In international co-authored publication networks, scientists from different countries and cultures are potential diversified knowledge sources. A country with high DC has a concentrated collaboration structure that can enable it to have more opportunities to obtain diversified knowledge from other countries and exert a higher influence on other countries, which can lead to the countries improving their research impact.

BC represents the proportion of the shortest paths in a network that pass through a given node. Moreover, it emphasizes the bridge role of the nodes (Freeman 1979). BC actors are better at controlling the flow of knowledge between most others (Burt 1992; Abbasi, Altmann, and Hossain 2011; Eldon, Chien, and Hsiuju 2013) and are likely to obtain non-redundant and rich knowledge especially when the other actors are not connected directly (Chi, Holsapple, and Srinivasan 2007), which would improve their research impact. A growing body of research has found that the BC of collaborative networks is positively correlated with citation counts (Yan and Ding 2009; Oguz, Kinglsey, and John 2014). Therefore, in a country-level collaboration network, BC represents a country's capability to broker information and resources. A country with high BC can access and integrate different resources or knowledge from different groups in the collaboration network (Yan and Ding 2009), which would improve the quality of its publications and increase the citation counts it receives.

Countries' Amount of Scientific Publications and Motivation of Sharing Knowledge with International Collaborators

It has been argued that knowledge is the most strategically important resource for creating and sustaining competitive advantage (Fang et al. 2007). Aulawi et al. (2009) argued that knowledge can be spread, implemented and developed through knowledge sharing. They further argued that knowledge sharing can stimulate an individual to think more critically and creatively, so that they can develop new knowledge. Knowledge sharing, where new innovations and ideas were aroused, was found to improve innovation performance (Jian, Liu, and Zhao 2010). Further, people can integrate knowledge received from the outside world with their own knowledge storage, arouse thinking and trigger knowledge innovation via knowledge sharing. The importance of knowledge sharing for collaborative work has been established in previous studies (e.g. Hendriks 1999). Storck (2000), for example, argued that sharing knowledge is important to building trust and improving the effectiveness of group work.

As noted earlier, the central actor of the international collaboration network is tied to many other actors and would have more opportunities of knowledge sharing (Anderson 2008), and accessing non-redundant and diverse information (Gnyawali and Madhavan 2001). However, the value of the central position depends on an actor's motivation of knowledge sharing (Anderson 2008; Moran and Ghoshal 1996). Individuals with a greater motivation to share knowledge would be expected to engage in more communication, which should result in mutual understanding and trust in international collaborations (Jeong, Choi and Kim 2014). Thus, we expect that a country's amount of scientific publications, as a proxy for its domestic knowledge and resources, may affect its motivation for knowledge sharing and accessing when collaborating with other counties. First, the number of publications a country has would likely be associated with the status it brings to international collaborations, which may affect its knowledge sharing motivations. A number of scholars have suggested that status, as reflected by academic position, is a key factor in research collaboration (Acedo et al. 2006; Jeong, Choi and Kim 2014). Researchers at lower academic levels are often required to produce more academic output than their more senior colleagues (Holley 1977). Thus, collaborations expected to provide higher productivity and publication rates (Laband and Tollison 2000) may appeal more to researchers at lower levels. Extending this perspective to a country level, the fewer scientific outputs the country has in a field, the more likely it is that the country will be short of material resources and intellectual knowledge and in a relatively low academic position in the field. Thus, countries with few scientific outputs will be more motivated to achieve a higher position. The existing research on international collaborations supports the idea that smaller output countries have been joining the core group of higher output countries at a growing rate over the last two decades (Wagner, Park, and Leydesdorff 2015).

We propose that small-size output countries would be more likely to undertake international collaborations than large-size output countries because international collaboration tends to result in a higher quantity and quality of publications than other research collaboration modes (such as personal research or domestic collaboration). Previous research has suggested that smaller countries often have higher proportions of international co-authored publications than larger countries and the proportion of international co-authored publications decreases as small countries grow in the number of scientific publications (Frame and Carpenter 1979; Kim 2000; Luukkonen, Persson, and Sivertsen 1992; van Raan 1998).

A second reason we expect that a country’s amount of scientific publications may affect its motivation for knowledge sharing and accessing when collaborating with other countries involving different roles in knowledge sharing. The knowledge sharing process consists of both donating knowledge and collecting knowledge (Hooff and Ridder 2004; Oldenkamp 2001; Weggemann 2000). Knowledge donating concerns communicating to others one’s personal intellectual capital, whereas knowledge collecting is related to consulting colleagues in order to get them to share their intellectual capital. Thus, countries with few scientific outputs and domestic intellectual knowledge are expected to act as knowledge collectors who actively communicate with foreign research partners and access foreign knowledge. In contrast, countries with many scientific outputs and resources are expected to act as knowledge donators with less to gain from foreign partnerships (Gumus 2007; Lin 2007).

Taking into account the existing literature on countries’ different statuses and roles in knowledge sharing, we expected that countries with large amounts of scientific publications would have a lower level of motivation for learning and sharing with their foreign partners than countries with a smaller amount of research output. Given the cultural, geographical and time zone differences inherent in international collaborations, if the actor is not an active sharer and learner, it will be very hard to create new ideas and high quality international co-authored collaborations. Thus, we propose that countries with a small amount of scientific publications will take more advantage from a central position in their international co-authored publication network.

In summary, our research objective is to empirically examine the impact of countries’ centrality of international co-authored publication networks on their citation counts and the moderating effect of countries’ amount of scientific publications on the relationship between them. We present the following hypotheses and theoretical model (Figure 1).

Hypothesis 1: Countries' degree centrality of international co-authored publication networks will be positively associated with their international co-authored publications' citation counts.

Hypothesis 2: Countries' betweenness centrality of international co-authored publication networks will be positively associated with international co-authored publications' citation counts.

Hypothesis 3: Countries' amount of scientific publications in the field will moderate the relationship between countries' degree centrality and their international co-authored publications' citation counts such that when the countries' amount of scientific publications in the field is low, the positive effect of countries' degree centrality on citation counts will be high.

Hypothesis 4: Countries' amount of scientific publications in the field will moderate the relationship between countries' betweenness centrality and international co-authored publications' citation counts such that when the countries' amount of scientific publications in the field is low, the positive effect of countries' betweenness centrality on citation counts will be high.

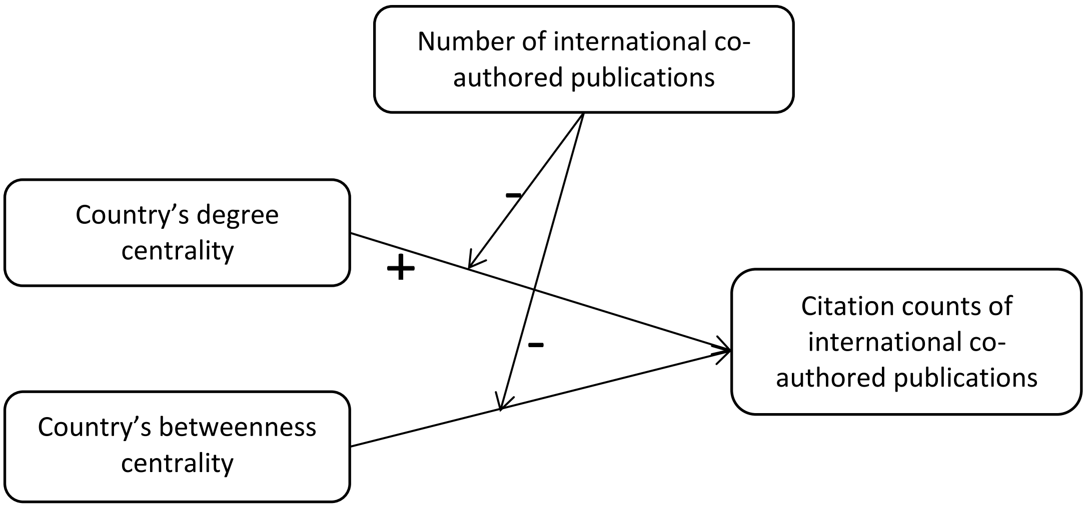

Figure 1: The Theoretical Model

METHOD

Data Collection

The unit of analysis in the current study was at the country level. The samples included the scientific discipline of creativity science. This discipline was chosen because it has attracted researchers from a large number of countries as more than 12.5 percent of its publications are international co-authored publications. In addition, there is a significant amount of variance in knowledge accumulation among the countries whose authors publish in this field. The creativity discipline is considered closely related to psychology, and the U.S. currently has the largest number of psychologists in the world. This is reflected in the large number of creativity articles (7,752) that have been published by U.S. authors, representing 35 percent of all creativity articles, as compared with 1,069 creativity articles published by authors from the People's Republic of China.

Data were collected from the Web of Science Core Collection database. We retrieved articles with the word 'creativity' as the search term, and excluded irrelevant articles detected through reading titles and abstracts. There were 12,894 articles written by authors from 118 countries from 2000 to 2014. 1,615 were international co-authored publications.

In order to conduct a longitudinal study from 2000 to 2014 and to ensure that each sample country had at least one international co-authored publication in every period, we selected the following 29 countries: USA, UK, China, Germany, Canada, Australia, Netherlands, France, Taiwan, Spain, Italy, Japan, Sweden, Israel, Russia, South Korea, Brazil, Denmark, Switzerland, Finland, Turkey, Austria, India, Singapore, New Zealand, Portugal, Norway, Belgium, and Romania. These countries' 1,570 co-authored publications accounted for 97.21 percent of all the international co-authored publications during that time period.

To calculate each country's centrality indicators in the international creativity research network, we downloaded the articles, extracted the country information from authors' addresses, and constructed the international co-authored publication network of each year from 2000 to 2014. We used the Science of Science Tool (Sci2 Team 2009) to process text files collected from Web of Science; used Pajek (Batagelj and Mrvar 2002) to generate format files; and ORA software (Carley 2014) to obtain matrices of the country-level co-authored publication network and calculate centrality indicators of each country.

Measures

Dependent variable. Citation counts were assessed as the sum of the citation counts of all of a country's international co-authored publications collected from the Web of Science core database on the last day of January in 2015. Two issues had to be considered before calculating national citation counts. First, we considered whether to use whole or fractional counting of author addresses. In whole counting each collaborating country receives one credit for its participation. In fractionalized counting a country is credited a fraction of a publication equal to the fraction of the author addresses from this country (1/n). The whole count method is the most commonly applied method of constructing citation indicators (Aksnesa, Schneider and Gunnarsson 2012; Gauffriau et al. 2007), with the exception of the Science and Engineering Indicator report published by the US National Science Foundation, in which articles and citations are counted on a fractional basis (National Science Board 2010). Both methods of calculating citation indices are considered correct (Aksnesa, Schneider and Gunnarsson 2012). Considering that we cannot fully judge a country's contributions to internationally co-authored publications based solely on its number of co-authors, we decided to use the whole count method.

Second, we considered the issue of normalization of citation counts. There are large differences in average citation rates among the various scientific disciplines and subfields (e.g. Hurt 1987). Garfield (1979) used the term 'citation potential' to describe this difference, referring to the fact that the average number of references per article is significantly lower in mathematics than in biochemistry. Moreover, there are significant differences in national scientific specialization profiles (Glänzel 2001). This means that countries with high relative publication activity in highly cited fields will have a comparative advantage. Zitt (2010) has proposed procedures to normalize the variability of citing practices between fields by utilizing a classification-free approach. However, because we selected a specific area to restrict our sample (creativity), normalizing the citation count was not necessary.

Independent variable. A country's degree centrality of the previous year's international co-authored publication network in this study was assessed by the following normalized index

(Wasserman and Faust 1994):

$$C_D(n_i) = \frac{\sum_{j=1}^{g} X_{ij}}{\text{V}*(\text{g}-1)} \quad i \neq j$$

The variable g refers to the total number of nodes in the network, and X_{ij} refers to the number of ties connected with node i and j directly. In order to compare the degree centrality of nodes across weighted networks of different sizes, we normalized degree centrality by dividing by V*(g-1), where V equals maximum link value of any two nodes.

Betweenness centrality of the previous year's international co-authored publication network was measured by the method developed by Freeman (1979):

$$C_c(\text{n}_i) = \frac{\sum_{j<k} g_{jk}(n_i)/g_{jk}}{(g-1)*(g-2)/2} \quad i \neq j \neq k$$

The variable g_{jk} is the number of shortest paths between j and k, $\text{g}_{jk}(n_i)$ is the number of shortest paths between node j and k that node i resides on, and g refers to the total number of points in the network. $\sum_{j<k} g_{jk}(n_i)/g_{jk}$ computes the total fraction of shortest paths that node i lies on. This value is then normalized by dividing the maximum number of shortest paths possible, (g-1)*(g-2)/2, to get the betweenness centrality.

Moderator variable. The amount of publications was measured by a country's total number of articles published in the creativity field in the current year.

Control variables. First, the number of international co-authored publications of a country in the current year was included as a control variable. Second, due to authors' self-citations (Lin and Huang 2012), the average number of authors per international co-authored article was included as another control variable (Biscaro and Giupponi 2014). Because previous studies found that citation counts increased over time (Kellsey and Knievel 2004), the third control variable was the publication year of the articles. The year was coded as a dummy variable in the regression model to be discussed in the results section.

Statistic Model

The data used in this study have two key features. First, the dependent variable (citation count) was a non-negative integer which can be included in a Poisson regression model. The mean of citation counts was 1.24, while the standard deviation was 3.39, which exceeds the mean. Because a Poisson regression model requires that the mean of the dependent variable be restrained to be equal to the variance (Demidenko 2013), it was not appropriate for the study, so we used a negative binomial model (Hausman, Hall, and Griliches 1984). The negative binomial model is an extension of the standard Poisson model, but it can handle over-dispersed data (Baba, Shichijo, and Sedita 2009; Cameron and Trivedi 2013). The formula of the negative binomial model appears below:

$$p(Y_i = y_i) = \frac{\Gamma(y_i + (1/\alpha))}{\Gamma(1/\alpha)\Gamma(1+y_i)} \left(\frac{1}{1+\alpha\mu_i}\right)^{1/\alpha} \left(\frac{\alpha\mu_i}{1+\alpha\mu_i}\right)^{y_i} \quad y_i = 0,1,2,3,\ldots$$

Where

$$\mu_i = E(Y_i) = \upsilon_i \left[e^{\sum_{j=1}^{k} x_{ij}\beta_j} \right] \quad i = 1, 2, 3, \ldots$$

Second, since we used panel data of 29 countries in a 15-year period, we investigated the appropriateness of a fixed effects vs. a random effects model. The results of Hausman tests suggested that the two-way fixed-effects model (country and year dimensions) was appropriate for our regression. In sum, we used a two-way fixed-effects negative binomial regression model to test our hypotheses.

RESULTS

The means, standard deviations, and correlations of the variables appear in Table 1. Countries' degree centrality and betweenness centrality had high positive correlations with the citation counts (r = .759, p < .01; r = .644, p < .01, respectively).

Next we proceeded with the two-way fixed-effects negative binomial regression models on citation counts (see Table 2). In the first model, the control variables (number of international co-authored publications, average number of authors per article), year dummy variable, and country dummy variable were entered. In the second and third model, the independent variables (degree centrality and betweenness centrality) were entered separately. In the fourth and fifth model, the interaction terms (amount of publications * degree centrality, amount of publications * betweenness centrality) were entered. The results indicated that a country's degree centrality of the international co-authored publication network positively affected its citation counts (see model 2, ß =19.892, p = .000). Thus Hypothesis 1 was supported. A country's betweenness centrality of the international co-authored publication network was not associated with its citation counts (see model 3, *ß* = 0.386, p = .878). Thus Hypothesis 2 was not supported. Countries' amount of publications moderated the relationship of degree centrality of the international co-authored publication network and their citation counts such that when countries' amount of publications increased, the positive effect of degree centrality on citation count was diminished (see model 4, *ß* = -.0109, p = .001). Thus Hypothesis 3 was supported. Countries' amount of publications also moderated the relationship of betweenness centrality of the international co-authored publication network and their citation counts such that when countries' amount of publications increased, the positive effect of betweenness centrality on citation count was diminished (see model 5, *ß* = -.028, p = .019). Thus Hypothesis 4 was supported.

To confirm the robustness of the results of the two-way fixed-effects negative binary regression, we transformed the dependent variable into a logarithmic form and conducted a multiple hierarchical regression analysis. The results were consistent with the results of the two-way fixed-effects negative binary regression (see Table 3).

To show the moderating effects directly, we constructed graphs. The graph of the publication amount's moderating effect on the relationship between degree centrality and citation counts shows that when the amount of publications of the country was high (above the mean value), the positive effect of degree centrality on citation counts was weaker than when the amount of publications of the country was low (below the mean value; see Figure 2).

Table 1: Mean, Standard Deviations and Correlations

	M	SD	1	2	3	4	5	6
Citation counts of internationally co-authored publications	95.448	225.686	1					
Number of international co-authored publications	6.834	12.540	.469**	1				
Number of authors per article	2.959	1.693	.113*	.218**	1			
Country's degree centrality	0.017	0.027	.759**	.637**	.224**	1		
Country's betweenness centrality	0.017	0.044	.644**	.802**	.139**	.821**	1	
Country's amount of publications	28.506	56.434	.490**	.710**	.371**	.632**	.622**	1

* $p < .05$, ** $p < .01$, ***$p < .001$

Table 2: Negative Binary Regressions

	Citation counts of international co-authored publications				
	Model 1	Model 2	Model 3	Model 4	Model 5
Number of international co-authored publications	0.103	-0.002	0.010	-0.004	0.005
Number of authors per article	0.009	0.007	0.009	0.013	0.029
Country's degree centrality		19.892***		29.345***	
Country's betweenness centrality			0.386		4.840
Country's amount of publications				0.005	-0.003
Amount of publications * Degree centrality				-0.109***	
Amount of publications * betweenness centrality					-0.028**
Log likelihood	-1773	-1762	-1773	-1756	-1769
Log likelihood ratio test	415.83***	437.02***	415.86***	449.49***	424.02***

* $p < .05$, ** $p < .01$, ***$p < .001$, two-tailed test. To be more concise, year and country dummy variables are not displayed.

https://dx.doi.org/10.22452/mjlis.vol22no3.1

Table 3: Multiple Hierarchical Regression Model

	Citation counts of international co-authored publications				
	Model 1	Model 2	Model 3	Model 4	Model 5
Publishing year	-0.344***	-0.161**	-0.289***	-0.179***	-0.338***
Logarithmic form of number of international co-authored publications	0.492***	0.265*	0.153	-0.021	0.199
Number of authors per article	-0.055	-0.084	-0.055	-0.024	-0.031
Country's degree centrality		0.502***		0.713***	
Country's betweenness centrality			0.065		0.421
Country's amount of publications				0.825***	0.653***
Amount of publications * degree centrality				-0.933***	
Amount of publications * betweenness centrality					-0.779**
N	359	359	359	359	359
Adjusted R^2	0.251	0.352	0.266	0.417	0.344
ΔR^2		0.101	0.015	0.065	0.078

* $p < .05$, ** $p < .01$, ***$p < .001$, model 2 and model 4 are compared with model 1, model 3 is compared with model 2, model 5 is compared with model

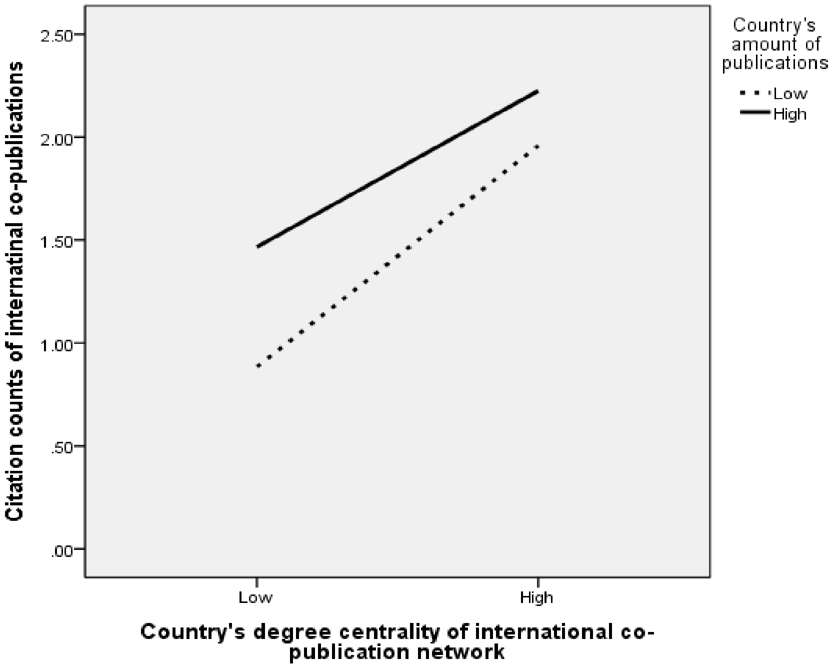

Figure 2: Moderating Effect on Country's Degree Centrality and Citation Counts

The graph of the publication amount's moderating effect on the relationship between betweenness centrality and citation counts shows that when the amount of publications of the country was high (above the mean value), the positive effect of betweenness centrality on citation counts was weaker than when the amount of publications of the country was low (below the mean value; see Figure 3).

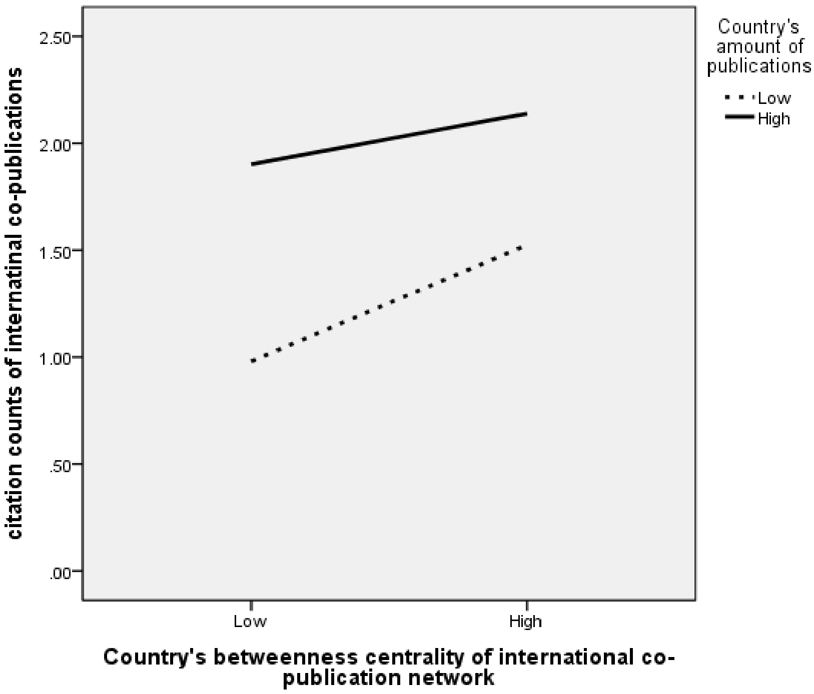

Figure 3: Moderating Effect on Country's Betweenness Centrality and Citation Counts

https://dx.doi.org/10.22452/mjlis.vol22no3.1

DISCUSSION AND CONCLUSION

First, our study demonstrated that a country's degree centrality positively affected its citation counts, which is consistent with prior research (Yan and Ding 2009; Oguz, Kinglsey and John 2014; Chan, Guness and Kim 2015). This finding enriches our understanding about countries' citation counts or research impact in a discipline. Second, we found that the country's betweenness centrality had no direct impact on its citation count, which conflicts with prior findings about the positive association between betweenness centrality and citation impact (Yan and Ding 2009; Oguz, Kinglsey, and John 2014). A possible explanation is that being a betweenness central country has costs, such as the time and effort to act as a bridge between authors in different countries. A practical implication is that authors in a country with a low level of knowledge accumulation should strengthen their collaborative relationships with a few partners and work toward degree centrality rather than betweenness centrality. Third, we found that countries with a small amount of publications would gain more benefits from their central position in terms of citation count. This finding may be explained by the fact that their lack of domestic scientific knowledge would motivate them to access more knowledge from their foreign partners, which in turn would help improve the quality of collaborative output. In contrast, for countries with more publications, their richer domestic knowledge makes foreign partners' knowledge less attractive or critical. Thus a big country in a central position might have less motivation to assess diversified knowledge from other countries, which explains why they received fewer citation counts from their central position in their international co-authored publication network.

Our study's findings should be considered within the context of previous research on international collaborations. Leydesdorff and Wagner (2008) observed that, from 2000 to 2005, international collaborations were dominated by a core group of fourteen nations with strong national systems. The authors proposed that the strength of this core group may put nations on the periphery at a disadvantage. However, Wagner, Park, and Leydesdorff (2015) updated this data for 2011 and found that all the countries of the world were actively engaged in globalization. Further, they found that new entrants to the network did not cluster around scientific 'leaders.' Taking together our findings with those of these researchers suggests that it is not necessary to be an author in a large country with a high level of knowledge accumulation in order to become a network member and obtain the benefits of international collaborations.

Before the results of the current study may be generalized, several limitations should be considered. First, we only examined the creativity research field. Previous research has found that international collaboration patterns vary widely in different fields such as in physics, chemistry and clinical medicine (Glänzel 2001). Future research should examine our hypotheses in other disciplines. Second, the amount of publications was regarded as the countries' level of scientific knowledge in the field. Other variables related to knowledge accumulation of the country should be considered in future research such as the number of related universities, Ph.D. students in the research field, and other resources in the country.

Keeping these limitations in mind, this study was among the first to examine whether the central countries of an international co-authored publication network would receive more citation counts from their international co-authored publications. Moreover, knowledge accumulation moderated the effect. The results of this study suggest that different countries should select different research polices to improve their research impact. For countries with a low level of knowledge accumulation in the field, frequent international co-authored publications would lead to a high research impact. Governments' encouragement of international collaborations and a more central position might be an effective approach to improve one's research impact globally. However, countries with a high level of scientific knowledge accumulation in the field should devote more attention to knowledge accessing and sharing when collaborating with co-authors in different countries. The findings of this study explain why countries with a low level of knowledge accumulation are actively engaged in research with co-authors in other countries. The findings also suggest that in order to get more from international collaborations, countries with a high level of knowledge accumulation should develop policies that motivate scientists to share and learn in their international collaborations more effectively.

ACKNOWLEDGEMENT

This work was supported by Chinese National Sciences Foundation Project numbers 71473238 and 71673264.

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https://dx.doi.org/10.22452/mjlis.vol22no3.1